COMPARING RAYTEQ PARALLEL HEATING ELEMENT WIRING WITH SERIES ELEMENT WIRING

SERIES-WIRED FURNACES – Many electric resistance melting furnaces are equipped with series-wired heating elements that are usually connected in a three-phase configuration.

But like inexpensive Christmas tree lights, all elements wired in series will stop operating when a single element in the group fails. This places the crucible in great thermal stress, risking catastrophic failure, as it faces blazing heat on one side and cold, dark heating elements on the failed side.

Worse yet, one third to one half of the furnace input power will be lost as a result of a single element failure, depending on whether the furnace is delta or wye connected. And when the second element fails two thirds to 100% of all furnace power will be lost! Obviously, the failure of a single element requires an immediate production stoppage so the furnace can be shut down for repairs.

Series connections are popular with some furnace manufacturers because they reduce manufacturing expense: there is no need for electrical wiring harnesses, junction terminals, fuse blocks, fuses or connection strips which have high labor content and are required for parallel-wired furnaces. An example of a series-wired electric resistance melting furnace is shown in Photo 1 below.

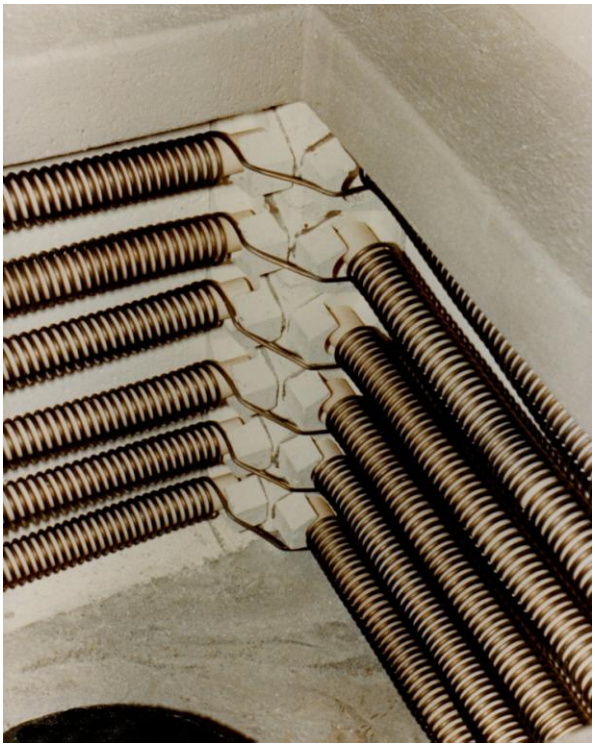

PHOTO 1 – EXAMPLE OF SERIES ELEMENT WIRING

Manufacturers of electric resistance furnaces equipped with larger diameter heater wire nearly always connect their heating elements in series groups. They do this because heating elements made from larger diameter wire have a very low electrical resistance which requires low voltage. Series connections offer an inexpensive way to reduce the voltage across each element. The alternative is to use a large, expensive step-down transformer which would raise the manufacturing cost appreciably.

It is well known that when one element in a series group fails, all other elements in that group stop operating. But it is less well known that the loss of a single element in a series connected, three phase floating wye configuration will immediately cut the input power to the furnace in half and that the loss of a second element will cut the furnace input power to zero!

To determine what happens when heating elements fail in a series connected furnace, it is useful to examine a particular example. Let's say we have a series-wired furnace with a power input rating of 75 kW (75,000 watts) which has twelve heating elements connected in a three-phase floating wye configuration. These elements would be wired per the diagram shown in Figure 1 below:

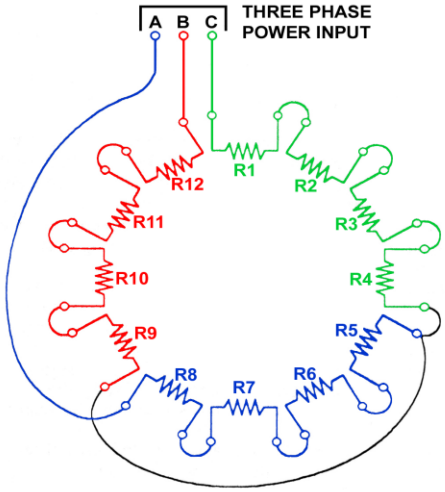

FIGURE 1 - WIRING DIAGRAM OF TYPICAL FURNACE WITH SERIES-CONNECTED ELEMENTS

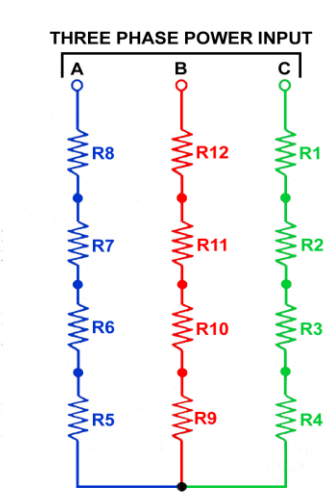

FIGURE 2 - SCHEMATIC REPRESENTATION OF FIGURE 1

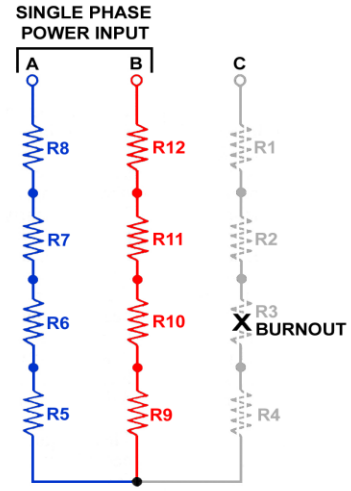

FIGURE 3 - SCHEMATIC OF FIGURE 1 WITH ONE ELEMENT BURNED OUT

The Figure 1 wiring diagram can be simplified and redrawn for clarification as shown in the schematic representation labeled Figure 2 next to Figure 1.

With an input voltage of 480 volts in any 3-phase, wye configuration, the voltage across each series group or "leg" will be 480/√3 = 277 volts. The voltage across each of the four heating elements in the three series groups shown in Figure 2 will thus be 277 divided by 4 = 69.25 volts. To determine the power rating of each individual heating element, we divide the total furnace power rating of 75,000 watts by 12 elements = 6,250 watts per element.

To calculate the resistance of each element, *Ohm's Law* tells us that R = V^2/W where R is the element resistance in ohms, V is the voltage across the element and W is the individual element power rating in watts. In this example, R = $(69.25)^2/6{,}250$ = 0.768 ohms.

Again, according to *Ohm's Law*, the current in amps (represented by I) flowing in each heating element will be I = W/V. For this particular example I = 6,250/69.25 = 90 amps. (This is a large current which can easily overheat the series connection junctions. The typical current in a Rayteq heating element is a much lower 15 amps.)

Now, when an element burns out in one leg, the diagram looks like Figure 3 below. Instead of the original three phase circuit, the burnout has left the remaining eight heating elements in series across a single 480 volt phase. The other four elements are completely out of the circuit because of the burnout and none are operating. The voltage across each of the eight remaining elements will now be 480 divided by 8 = 60 volts instead of 69 volts as before. This voltage drop will reduce the power dissipated in each element.

To determine what this reduced power will be, we again look to *Ohm's Law* which states that W = V^2/R. Now, at the reduced voltage caused by the burnout, the power dissipated by each element is W = $(60)^2/0.768$ = 4,688 watts. Thus, the total power dissipated in this furnace after a single element burnout is now 8 times 4,688 watts = 37,500 watts which is exactly half the original input power of 75,000 watts! No wonder the furnace must be immediately shut down and repaired!

What happens when a second element burns out? The entire remaining series group of eight elements go out of operation and the total furnace power dissipation is *zero!*

RAYTEQ MELTING FURNACE WITH PARALLEL-WIRED HEATING ELEMENTS

PARALLEL-WIRED FURNACES – In a Rayteq parallel-connected furnace with independently wired heating elements, all other heating elements will keep working if one element should go out of service. A furnace with 24 heating elements will lose just 1/24th of its melting rate with the loss of a single element and production can continue without a shutdown. This makes the extra investment for the parallel wiring very cost effective since it pays for itself in uninterrupted production after the first element goes out of service. The interior of a Rayteq parallel-wired furnace is shown in Photo 2 above.

A simple example of Rayteq's parallel heating element wiring is shown in Figure 4. Note that the "A", "B", and "C" phases rotate from one element to the next so that the failure of one phase will not result in a huge cold spot on one side of the crucible. A schematic representation of Figure 4 is shown in Figure 5.

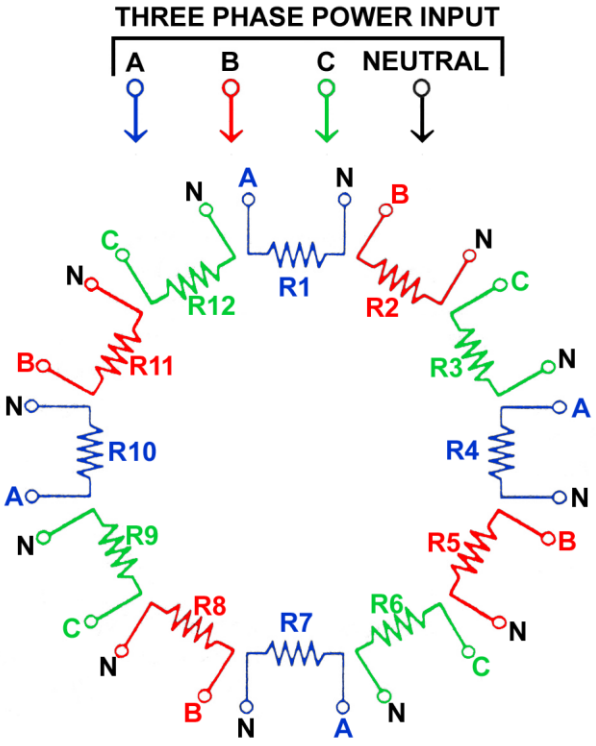

FIGURE 4 - HEATING ELEMENT CONFIGURATION OF RAYTEQ PARALLEL WIRED FURNACE
(connections not shown for clarity)

If one element goes out of service for any reason, we have the situation shown in Figure 6. Most importantly, with parallel wiring the loss of any element never affects any other elements as is the case with series wiring.

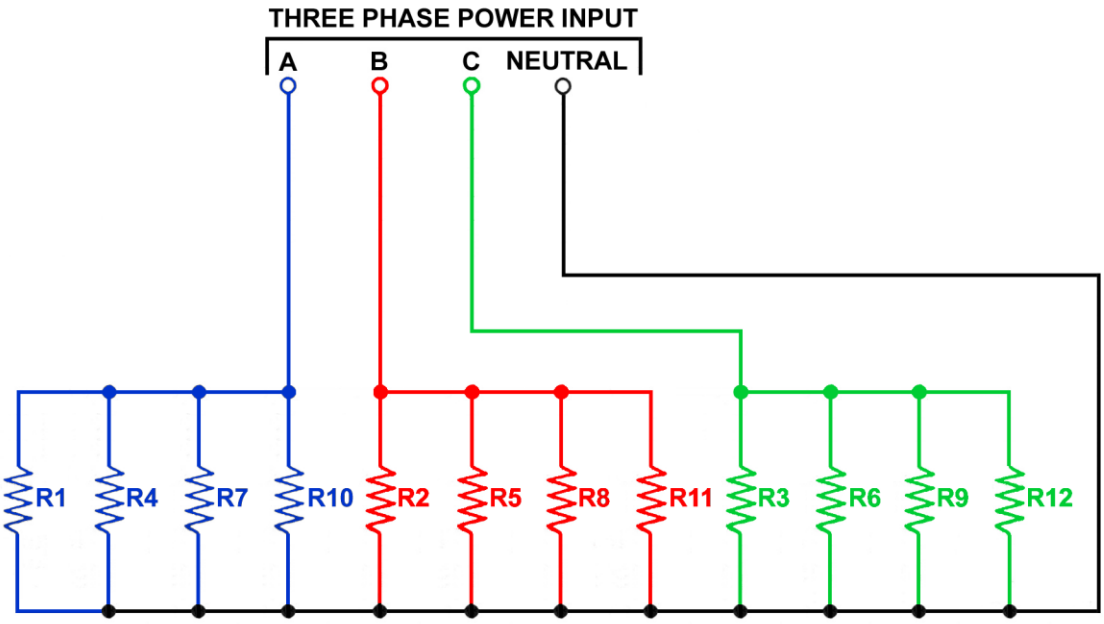

FIGURE 5 - SCHEMATIC
REPRESENTATION OF FIGURE 4

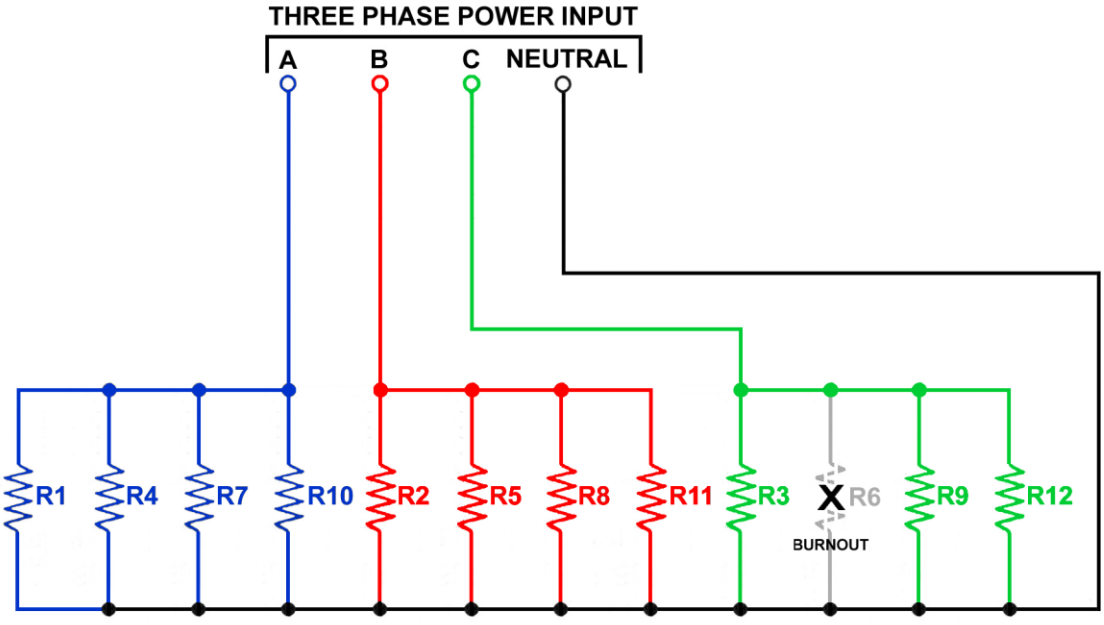

FIGURE 6 - SCHEMATIC OF FIGURE 5
WITH ONE ELEMENT BURNED OUT

For a useful comparison, Rayteq's Model R-475 melting furnace has eighteen heating elements wired in parallel and a total power input of 81 kW. If one heating element goes out of service, all other elements remain in full operation and the furnace loses just 1/18 of the input power or 4½ kW. If a second heating element goes out of service, the furnace loses 2/18 of the input power or just 9 kW. Thus, with two elements out the furnace is still at 89% power and the reduction in melt rate can hardly be noticed.

This is quite a contrast to the series connected example above where the furnace drops to half power when one element burns out, then to zero power when two elements burn out. This example should help clarify why Rayteq furnaces are wired with 100% parallel heating element connections for maximum up-time reliability.

CHECKING FOR SERIES OR PARALLEL WIRING

The prospective buyer should carefully check and verify whether the furnace being considered is parallel or series-wired. Most manufacturers will immediately confirm which type of wiring they are offering. Sometimes confusion arises if a manufacturer claims its furnaces are parallel-wired or "series/parallel wired" when, in fact, they are 100% series connected.

In advance of purchase, to insure he gets 100% parallel wiring, the prudent buyer should (a) request a detailed wiring diagram which shows the wiring of every element in the furnace to ascertain that the furnace is truly parallel-wired and, if necessary, obtain the services of a skilled electrician (or Rayteq) to confirm it; and (b) receive a written pledge from the manufacturer that the furnace can be returned for a full refund if it should arrive with series wiring.

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